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SUMMARY REPORT 1979-1982

LINEAR AND NONLINEAR ULTRASONIC INTERACTIONS ON LIQUID-SOLID BOUNDARIES

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A summary report listing tasks performed and complete reference listing of all publications originating from Contract during reporting period.

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Summary Report

This report is being prepared upon the request of the Sponsoring Agency, Office of Naval Research, Physics Programs, to serve as a complete index to all research performed under Task NR 384-928, Contract N00014-78-C-0584. It covers the period 9/78 to 3/82.

The topic of investigation is Linear and Nonlinear Ultrasonic Interactions on Liquid-Solid Boundaries. Most of the earlier investigations constituted an extension of another ONR Contract which was concerned with an ultrasonic scale model study of sonic reflection from Arctic ice. Some phenomena studied there warranted special attention, and the present Contract supports these studies. The main emphasis was placed on reflection and transmission of a bounded ultrasonic beam since it had been found that plane wave theory (as almost always used in the past) does not explain the existence of nonspecular ultrasonic reflection from interfaces, where "nonspecular reflection" refers to beam displacements, beam split-up, intensity distribution changes within the reflected beam, and other similar phenomena. Such nonspecular reflections occur for simple liquid-solid interfaces when the incident beam impinges at the Rayleigh angle and, for solid plates immersed in a liquid, at Lamb mode angles.

The first topic of investigation was to compare the predictions of plane wave reflection theory to actually observed beam reflections from asymmetrically loaded solid plates (1). It was found that some plate modes cannot be excited easily by the appropriate Lamb mode angle of incidence. Thus a more fundamental theoretical problem had to be solved first, i.e., the investigation of the restrictions on the excitation of Rayleigh waves (2). Here it was found that leaky Rayleigh waves cannot always be excited [1] even if the velocity difference between liquid and solid suggests that excitation can be accomplished. This study was extended to surface waves in general (3).

References in () refer to journal articles, in [] to abstracts of talks at meetings, both listed in Bibliography.

While the investigation of nonspecular reflection for Rayleigh and Lamb mode incident angles was continuing, it was found that nonspecular phenomena may also occur at other critical angles [2]. Specific conditions for the observability of nonspecular reflection at and near the longitudinal critical angle were found (4).

An extension to include nonspecular transmission phenomena at layered media was made possible through the development of a numerical integration method [3]. This mathematical method was first applied to the simple liquid-solid interface case, with the incident beam at the Rayleigh angle (5). Experimental verifications were reported [4] at the Tenth ICA.

Optical methods were used for the measurement of reflectivity from solid plates immersed in a liquid (6) in order to confirm the expected agreement between theory and experiment. This agreement gave rise to a general description of nonspecular reflection and transmission effects for layered media (7), and in particular, transmission effects for solid plates (8). Some associated problems were solved, e.g., the reducibility of the plane-wave reflection coefficient for plates to that of a simple liquid-solid half space arrangement. A unified picture of this reducibility was given [5], showing that inclusion of absorption into the formulism is absolutely essential. A worked out example, letting the plate thickness increase to infinity, showed the gradual change of the reflection coefficient from a plate-like behavior to an infinite half space (9).

The results of this phase of the work can be used to make a judgement whether a "thick" plate immersed in a liquid can or cannot be treated as a plate or as an infinite medium.

It was also found that reflection and transmission is greatly influenced by beam profile and plate mode structure (10), where any localized small variation in the plate shows up as a distinct change in the beam reflection profile [6].

Nonlinear effects in Lamb mode propagation were investigated (11) via acousto-optic methods and were described by Green's functions. This work is now being concluded and is, so far, described in a thesis (T. S. C.), listed in the Bibliography.

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